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FOR

HALFTONE SCREEN FREQUENCY AND MAGNITUDE ESTIMATION FOR DIGITAL DECSCREENING OF DOCUMENTS

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HALFTONE SCREEN FREQUENCY AND MAGNITUDE ESTIMATION FOR DIGITAL DECSCREENING OF DOCUMENTS

This application is based on a Provisional Patent Application No. 60/393,244 filed 07/01/2002.

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is related to the following co-pending applications: Serial No. 10/187,499 (Attorney Docket D/A1270) entitled "Digital De-Screening of Documents", Serial No. 10/188,026 (Attorney Docket D/A1270Q) entitled "Control System for Digital De-Screening of Documents", Serial No. 10/188,277 (Attorney Docket D/A1271Q) entitled "Dynamic Threshold System for Multiple Raster Content (MRC) Representation of Documents", Serial No. 10/188,157 (Attorney Docket D/A1271Q1) entitled "Separation System for Multiple Raster Content (MRC) Representation of Documents", and Serial No. 60/393,244 (Attorney Docket D/A2303P) entitled "Segmentation Technique for Multiple Raster Content (MRC) TIFF and PDF all filed on July 01, 2002 and all commonly assigned to the present assignee, the contents of which are herein incorporated by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates generally to methods and systems for image processing, and more particularly to methods and systems for de-screening digitally scanned documents.

DESCRIPTION OF RELATED ART

Almost all printed matter, except silver-halide photography, is printed using halftone screens. The need to estimate the halftone frequency and magnitude stems from the fact that almost all printed matter, with the exception of a few devices like dye-sublimation or silver-halide photography, is printed out using halftone screens. These halftones are very specific to the printing device and when scanned and re-halftoned may cause visible artifacts and/or unacceptable Moiré patterns if not properly removed. The suppression of halftones is especially important for color documents, since these are typically printed with four or more color separations containing slightly different screens at different angles and or frequencies, and these may interact with each other to cause undesirable spatial artifacts.

The successful removal of the original halftone screens is based on the ability to accurately estimate the local frequency. Therefore there is a need for an improved method and apparatus for estimating the halftone screen frequency and magnitude.

SUMMARY OF THE INVENTION

An efficient method and system for eliminating halftone screens from scanned documents while preserving the quality and sharpness of text and line-art is disclosed. The method and system utilizes one or more independent channels with different sensitivities (e.g., Max, High, and Low) to provide high quality frequency and magnitude estimation. The most sensitive channel (Max) derives the frequency estimate, and the remaining channels (e.g., High and Low) are combined to create the screen magnitude. The Max channel is the most sensitive and will usually report the existence of frequencies even when the screen is very weak. Therefore, the screen frequency must be additionally

qualified by the screen magnitude. The screen magnitude can be interpreted as the level of confidence that the local neighborhood represents half-toned data.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become apparent from the following detailed description of the present invention in which:

FIG. 1 is a block diagram of the system of a Screen estimator Module.

FIG. 2 illustrates one-dimensional filter responses of various filter units.

FIGS. 3-5 illustrates two-dimensional filter responses of various units.

FIGS. 6A and **6B** illustrates a typical 3x3 max module structure.

FIGS. 7A and **7B** illustrates a typical 3x3 contrast module structure.

FIG. 8 shows a min-max detection structure within a 3x3 window.

FIGS. 9A and **9B** illustrates a single interpolation unit.

FIG. 10 is a block diagram of a structure of one dual bilinear interpolation units.

FIG. 11 illustrates a screen magnitude estimation equation.

DETAILED DESCRIPTION OF THE INVENTION

A new method and system are described for de-screening digitally scanned documents such that potential halftone interference and objectionable Moire patterns are eliminated or substantially reduced. Referring now to **FIG. 1**, a block diagram of the method and system of the

present invention is represented by a Screen Estimator Module SEM. The Screen Estimator Module is responsible for estimating the instantaneous halftone frequency and magnitude (strength) at the current pixel of interest. The Screen Estimator Module operates on an 8-bit source image Src **28**, and produces an 8-bit halftone frequency estimate Scf **70**, and an 8-bit halftone magnitude estimate Scm **72**.

The need to estimate the halftone frequency and magnitude stems from the fact that almost all printed matter, with the exception of a few devices like dye-sublimation or silver-halide photography, is printed out using halftone screens. These halftones are very specific to the printing device and, when scanned and re-halftoned for printing may cause visible artifacts and/or unacceptable Moiré patterns if not properly removed. A De-Screen Module (DSC) as described in Applicant's co-pending application, Docket D/A3010, relies on the information that is produced by the Screen Estimator Module in order to eliminate (filter out) the original halftone patterns from the original scanned image. The suppression of halftones is especially important for color documents, since these are typically printed with four or more color separations containing slightly different screens at different angles and or frequencies, and these may interact with each other to cause undesirable spatial artifacts.

The Screen Estimator Module is comprised of one or more frequency estimation (e.g., Mx, Hi and Lo) working in parallel. The first Mx channel **30** is used for estimating the screen frequency Scf **70**. The remaining channels (e.g., Hi **40** and Lo **50**, respectively) are combined together at the very end to form the screen magnitude signal Scm **72**. For high quality estimation of small point color-halftoned text, it may necessary to use two or more channels

for the screen magnitude estimate in order to cover the desired frequency range of interest.

In one embodiment, the Screen Estimator Module SEM may use up to three frequency channels at different levels of sensitivities. The upper Mx channel **30** in **FIG. 1** is tuned for maximum frequency sensitivity at the full source resolution and therefore is used for deriving the screen frequency estimate signal Scf **70**. However, this channel is very sensitive and will usually report the existence of frequencies even when the screen is very weak. Therefore the screen frequency must be additionally qualified by the screen magnitude Scm **72**.

The Hi channel **40** in **FIG. 1** is tuned for moderate frequency sensitivity that is less sensitive than the Mx Channel **30**. The two Channels Mx **30** and Hi **40**, operate at the full source resolution. The Lo channel **50** is also tuned for moderate sensitivity. However, in contrast to the Mx **30** and Hi **40** Channels, the Lo **50** Channel is operating on a sub-sampled signal, outputted from the triangular Lo Channel filter F3/2 **56** at half the source resolution in each direction. The screen magnitude signal Scm **72** is derived from the analysis of one or more the frequency estimates that are produced by Hi **40** and Lo **50** Channels.

Each frequency channel is made up of a plurality of Min-Max texture detectors MM3 **31**, **32** and **33** to be described below, followed by averaging filters **41**, **42** and **52** respectively. The Mx **30** and Hi **40** Channel MM3 **32** units operate on the single channel 8 bit incoming source signal Src **28**, while the Lo Channel MM3 **32** operates on a sub-sampled signal at half the resolution. The Lo Channel F3/2 filter **56** is responsible for filtering and sub-sampling the

source signal Src **28** by a factor of 2x in each direction and driving the Lo Channel MM3 unit **32**.

The three MM3 Min-Max modules **31**, **32** and **33** are used for finding peaks and valleys in the 2D input signal. Since the Mx **30** and Hi **40** Channels share the same Src input signal **28**, they duplicate the first stage calculations of a MM3 unit **32**. However, different thresholds are applied in the second stages of the two units producing the two independent results. The dotted line **27** in **FIG. 1** is intended to serve as a reminder that the front-end portions of the two MM3 units **32** may be computed once and then shared.

A detailed description of the Min-Max detector units is given below. The units are basically examining the content of a 3x3 window centered on the current pixel of interest and analyzing, using adaptive thresholding, if the center pixel is significantly larger or smaller relative to its eight surrounding neighbors. If so, the center pixel is regarded to be a peak (if larger) or valley (if smaller) respectively. By counting the number of peaks and valleys per unit area, a measure of the local frequency is obtained.

Each MM3 unit outputs **31**, **32** and **33** have only 1 bit of precision, but each is scaled by a configuration factor DotGain prior to the first subsequent stage of filtering. Each unit operates one or more color channel of the input signal. However, in this embodiment only 1 channel, the luminance channel is used. The DotGain factor for the Lo channel **50** is divided by some factor, such as 4. Note this scaling can be postponed to the normalization step of the first subsequent filter by adjusting that stage's normalization factor.

The outputs from the MM3 Min-Max detectors **31**, **32** and **33** are passed through different averaging and sub-sampling filters. In order to avoid aliasing problems with the sub-sampling, the spatial filter span in each case is twice the sub-sampling ratio minus one. The Mx Channel **30** uses a triangular 2D F63/32 filter **32** that reduces the bandwidth by a factor of 32x in each direction (approx. one-thousandth of the source bandwidth).

Likewise, the Hi Channel **40** MM3 output is applied to a cascade of two triangular 2D subsampling filters – the F31/16 filter **42** and F3/2 filter **46**. The output from the cascaded filtering units is also sub-sampled by a factor of 32x in each direction (16x in the first filter and 2x in the second), and therefore the output is at the same data rate as for the Mx Channel **30**.

Similarly, the Lo Channel **50** uses a cascade of two triangular 2D filters F15/8 **52** and F3/2 **46**. The output from the second filtering unit is also sub-sampled by a factor of 32x in each direction (2x first by F3/2 followed by 8x and 2x). The higher bandwidth data paths are noted in **FIG. 1** using wide black lines for the source bandwidth, lighter lines for 1/16 the bandwidth, and thin black lines for 1/32nd the bandwidth. The reduction factor is also specifically noted by the numbers.

In both the Hi **30** and Lo **40** Channels, a sample of the 1/16 resolution signal is passed to MX3 units **44**. These perform a 3x3 Max operation (gray dilation). The outputs are sent to the b input of each Channel Dual Bilinear Interpolation unit DBI **54**, respectively.

Unlike the Mx Channel **30**, the magnitude estimates Hi **40** and Lo **50** Channels contain an additional smoothing/averaging F5 **64** stage to further

reduce spatial noise. The F5 units **64** are 5x5 triangular weight (non-subsampling) filters. The filtered outputs from these units are sent to inputs of their respective Dual Bilinear Interpolation units DBI **54**. The outputs are also are passed through the C3 contrast units **48** which search for the maximum difference in a 3x3 window centered on the current pixel. The C3 outputs become the c inputs to the DBI units **48**, respectively.

The Mx Channel **30** averaged at 1/32 resolution is sent to a bilinear interpolation unit SCF **36**. The 3 signals produced by each of the Hi **40** and Lo **50** Channels are sent to their respective DBI units **54**. These units perform dual bilinear interpolation to bring the sub-sampled input resolution back to the original source resolution. The a and c DBI inputs are at 1/32 resolution and the b inputs are at 1/16 resolution. The output bandwidth from the interpolation units is substantially higher than the input. For example, with the factor of 32x above, the interpolation units produce 1024 output pixels for each input pixel.

The interpolated output of the Mx Channel **30** interpolation unit SCF **36** is the 8-bit estimated screen frequency Scf **70**. The outputs of the other channels such as Hi **40** and Lo **50** Channels Dual Interpolation units (Hi and Lo) are combined together in the Magnitude Estimate Module SCM **61**. Its output is the 8-bit estimated screen magnitude signal Scm **72**. The estimated screen frequency and magnitude signals Scf **70** and Scm **72** are exported to the De-Screen Module DSC and (Scm only) to the Segmentation Module SEG (both not shown). A more detailed description of the various elements of the Screen Estimator Module is provided below.

FIG. 2 illustrates one-dimensional filter responses of various filter units and **FIGS. 3-5** illustrates two-dimensional filter responses of various units. These Filtering Units are used for the purpose of smoothing or averaging the

input signals to remove high frequencies. Each filter unit implements a square, separable and symmetric 2D FIR (Finite impulse response) filter. The filter response is identical in the horizontal and vertical directions. If the input to the filter is a color signal, the same filter response is independently applied on each one of the color components. The 1D filter **60** response has a symmetric triangular shape with integer coefficients as illustrated in **FIG. 2**. The particular filter shape (but any other filter shapes are covered) was chosen for ease of implementation.

The general filter form is referred to as an Fn/k filter, where n is the filter size (overall span in either x or y) and k is the amount of sub-sampling that is applied to the filtered output in each direction. The sub-sampling factor k is omitted when k = 1. Note that in this document the filter span n is assumed to be an odd integer (n = 1, 3, 5,...) such that the 2D filter response has a definite peak at the valid center pixel location.

Examples for the 1D and 2D filter response are illustrated in **FIGS. 1** and **2**. **FIG. 2** shows the non-normalized 1D filter **60** response for F3 and F11, and **FIGS. 3** through **5** shows the resulting non-normalized 2-D coefficients for F3 **62**, F5 **64**, and F7 **66**, respectively.

Since the filter is separable, the 2D filter response can be implemented by cascading two 1D filters in the horizontal and vertical directions. The filters are all operating at the full input data rate, but the output may be sub-sampled by a factor of k in each direction. In many cases, although not always, the filter size n and the sub-sampling factor k satisfy the following relationship:

$$\mathbf{n} = 2 * \mathbf{k} - 1$$

This represents 50% coverage overlap relative to the sub-sampled area. As an example, the overall 2-D response of the smallest 3x3 filter, F3 **62**, is:

$$\mathbf{F\_3} = \frac{1}{16}\begin{bmatrix}1\\2\\1\end{bmatrix} * (1, 2, 1) = \frac{1}{16}\begin{bmatrix}1 & 2 & 1\\2 & 4 & 2\\1 & 2 & 1\end{bmatrix}$$

Larger filters are similarly described. Since these filters are separable, it is best to implement them in two 1D steps, orthogonal to each other. Each filter output is normalized by the sum of the coefficients to make it fit back into the 8-bit range. Some filters, such as an F3 filter **62**, have a total sum of weights that is a power of 2 numbers. These filters will require no division in the normalization step as it can simply be implemented as a rounding right shift of 2. For example, the F3 filter **62** has a total 1D weight of 1+2+1 = 4. A rounded division by this weight could be accomplished with an add of 2 followed by a shift right by 2.

normalizedResult = (sum + 2)>>2

In general, when rounding is called for, it is typically applied by adding in half the divisor prior to performing the shift. Since right shift, performed on 2's complement coded binary numbers is the equivalent of floor (numerator/2^shift), adding half the divisor causes nearest integer rounding for both signed and unsigned numerators.

When the total weight of a filter does not add up to a power of 2, the compute-intensive division operation is avoided by approximating it using a

multiplication by ratio of two numbers, where the denominator is a chosen power-of-2 number.

The subsampling filters F3/2 F15/8 F31/16 and F63/32 all have power of 2 1D weights: 4,64,256 and 1024 respectively. So normalization is just a rounding right shift. The F5 filter **64** has a 1D weight of 9 and can be approximated by multiplication by 57 prior to a rounding right shift by 9 positions. Note that multiplication of x by 57 can be done without using a variable multiply by using shift/add/sub operations such as:

$$x*57 = x \ll 6 - x \ll 3 + x$$

Referring to **FIGS. 6A** and **6B**, the MX3 Max units **32** used in the Hi **40** and Lo **50** Channels search for the maximum value in a 3x3 window centered on the current pixel **74** of interest. The input is an 8-bit signal. The search for the max value is performed over the 9 pixels of the 3x3 window. This gray dilation module produces an 8-bit output that is made up of the largest pixel value **76** found within the boundaries of the search window. The MX3 max algorithm is illustrated in **FIG. 6B**.

Referring now to **FIGS. 7A** and **7B**, these C3 Contrast modules **48** are designed for measuring the amount of local contrast at the input. The contrast is defined as the difference between the largest and smallest pixel values within a window centered on the current pixel **74** of interest. The C3 Contrast units **48** utilize a window size of 3x3, centered on the current pixel **74** of interest. The input to the contrast units is an 8-bit signal. The contrast module produces an 8-bit monochrome output (single channel) **84**. The operation of the C3 Contrast Units **48** is illustrated in **FIG. 7B**. The operation is as

following: for each pixel location, the content of a 3x3 window is independently searched for the minimum and maximum pixel values. The output contrast value is defined to be:

$$\text{Contrast} = \max - \min$$

Since the largest and smallest pixel values are always between 0 and 255 for an unsigned 8-bit input signal, the contrast is guaranteed to be in the range [0…255], and no special normalization is necessary.

The three Min-Max Detection modules **31**, **32** and **33** are used for finding peaks and valleys in the input signal. By counting the number of peaks and valleys per unit area, a measure of the local frequency is obtained. Each one of the Mx **30**, Hi **50** and Lo **40** Channels uses a similar MM3 unit **31**, **32** and **33**. The one difference between the three units is that each unit uses a different set of thresholds to adjust the frequency sensitivity of the corresponding channel and the Lo Channel MM3 **32** is operating at ¼ the speed of the other two.

All 3 units **31**, **32** and **33** operate on a one component gray source. Each unit utilizes 3x3 window to indicate when the center pixel is at an extreme value (either peak or valley) relative to its 8 neighbors, following the logic below. The output from each Min-Max Detection units **31**, **32** and **33** is a 1-bit signal indicating that the corresponding Src pixel is in an extreme value state (can be extended to other color channels as well).

The MM3 Min-Max Detection structure is depicted in **FIG. 8**. For each pixel, the outer ring of 8 pixels surrounding it (the current pixel of interest) is

first analyzed. The 8 outer pixels are further divided into two sets of 4 pixels each as shown in **FIG. 8**. The partitioning of the outer ring into two sets is useful for reducing the likelihood of false alarms in detecting straight-line segments as halftones (since most commonly encountered halftones are likely to be clustered dots).

For each set, the pixel values are compared among the members **78** and **86** of the set to determine the minimum and maximum values within each set independently:

$$A_{max} = \max (Aij) ; \text{ over all } (i, j) \text{ belonging to the set A}$$

$$A_{min} = \min (Aij) ; \text{ over all } (i, j) \text{ belonging to the set A}$$

$$B_{max} = \max (Bij) ; \text{ over all } (i, j) \text{ belonging to the set B}$$

$$B_{min} = \min (Bij) ; \text{ over all } (i, j) \text{ belonging to the set B}$$

From these, the overall outer ring and total min are computed. Using the total min and 2 configuration parameters, a noise level is then computed.

$$\text{Noise} = \text{ConThr} + X^*\text{NoiseFac}/256$$

The center pixel **74** value X is defined to be at a peak if it is [significantly] larger than the maximum pixel value of either set:

$$\text{If } [(A_{max} + \text{Noise} < X) \text{ AND } (B_{max} \leq X)] \text{ return}(1)$$

Similarly, the center pixel **74** value X is defined to be at a valley if it is [significantly] smaller than the minimum pixel value from either set:

$$\text{If } [(A_{min} > X + \text{Noise}) \text{ AND } (B_{min} \geq X)] \text{ return(1)}$$

The above equations determine the two conditions where the output from the 3x3 detection window are set to 1; in all other cases the output will be set to 0.

The Screen Frequency and Magnitude Module SEM makes use of one Bilinear Interpolation Unit SCF **36** and two Dual Bilinear Interpolation Units DBI **54**. The Single Interpolation Unit SCF **36** is applied to the high sensitivity frequency estimation Mx Channel **30**, as shown in **FIG. 9A**, to generate the screen frequency signal SCF **70**. The Hi **40** and Lo **50** Channel DBI Dual Interpolation Units **54** are used prior to combining them together to form the screen magnitude SCM **72**.

The three interpolation modules interpolate (up-sample) the signal back to the source resolution. The input signals are up-sampled by a factor of 32 in each direction to restore it to the original resolution. Each interpolation unit is performing bilinear interpolation, essentially generating 32*32 = 1024 pixels for each original pixel. The step size of the bilinear interpolation is $1/32^{nd}$ of the original pixel grid. The following paragraphs describe in more details the Single and Dual Interpolation Units.

The Single Interpolation Unit SCF **36** is applied on the sub-sampled output of the screen frequency estimator Mx Channel **30**. The purpose is to restore the Mx Channel **30** output to the full source resolution of the input to the Screen Estimator Module SEM. The Interpolation technique is based on a

2D bi-linear interpolation by a factor of 32x in each direction. After interpolation, the instantaneous screen frequency estimate signal SCF is forwarded to the De-Screen Module DSC.

The block diagram of the Single Interpolation Unit SCF is shown **FIGS. 9A** and **9B**. The input to the Unit is the sub-sampled Mx Channel output representing the screen frequency. For each input pixel, the unit produces 32 x 32 = 1024 output pixels. The thick lines in **FIG. 9A** note the higher output bandwidth. Both the input and output are 8-bit monochrome signals. The output is the 8-bit screen frequency estimate signal Scf **70**.

The operation of the Single Interpolation Units SCF **36** is illustrated at the **FIG. 9B**. The circled locations **88** and **90** indicate the location of the input pixels. The output pixels are located at the grid intersection points. Note that for simplicity, **FIG. 9B** only shows an interpolation factor of 8x in each direction, although the actual unit is required to support a factor of 32x in each direction. The step size for the bilinear interpolation is $1/32^{nd}$ of the original pixel grid. The details of implementation are straightforward.

The Hi and Lo Channel DPI Dual Interpolation Units are similar to the Single Interpolation Unit SCF, except that there are two interpolation stages with an additional blending operation in the middle. The Structure of one of the Dual Interpolation Units is shown in **FIG. 10**. The Dual Interpolation Units operate on 3 signals **94, 96** and **98** generated in each of the Hi and Lo magnitude estimate channels.

As can be seen in **FIG. 10**, each Dual Interpolation Unit is composed of two interpolation stages **100** and **102**, respectively. The first stage includes the

interpolation **100** of the A_5 **94** and C_5 **98** inputs by 2x in each direction. The interpolation **100** uses a simple bi-linear interpolation technique. The A_5 input **94** corresponds to the output of the F5 filter **64** units. Note the subscripts in **FIG. 10** correspond to the level of subsampling. The subscript 5 indicates that the signal has been subsampled 5 times by a factor of 1/2 (1/32 total). The C_5 input **98** corresponds to the output of the 3x3 contrast units. As indicated in **FIG. 1**, both of these inputs have been previously sub-sampled by a factor of 32x in each direction. After interpolating the A_4 and C_4 outputs, of this first stage of interpolation are subsampled by 1/16. That is the same subsampling level of the B_4 input **96**. It is now possible to compute BmA_4, the B_4 minus A_4 difference signal **104**. BmA_3 is multiplied by the magnitude fine blend factor MFB_3 that is generated by applying C_4 to the MagFineBlenVsCon function **106**. The $BmAxC_4$ signal is the result of multiplying **108** BmA_4 times MFB_4 and shifting right by 8. This gets added to A_4 in 110 to create HI_4 or LO_4 signals depending on the channel. The results are then fed to the 16x bilinear interpolation unit **112** producing the Lo or Hi output depending on the channel.

The MagFineBlenVsCon function **106** above is a programmable function. In one embodiment, the typical MagFineBlenVsCon function **106** above can be easily computed as y = (x-16)*12 where the output is then clamped between 0 and 192. The equations below incorporate this typical configuration value of MagFineBlenVsCon **106**.

$$BmA_4 = B_4 - A_4$$

$$MFB_4 = MagFineBlendVsCn3(C_4) = \max(0, \min(192, (C_4-16)*12))$$

$$BmAxC_4 = (BmA_4 * MFB_4) >> 8$$

The purpose of this arrangement is to refine the magnitude estimate in places where it is subject to change. When the frequency magnitude estimate in one of the channels appears to be stable and constant, its value is used as the blended output. This happens due to the C_4 signal from the contrast measuring unit being close to zero, thereby selecting the A input. However, if the magnitude estimate begins to change, the C_4 signal increases, and the content of B_4 begins to influence the blended output. C_4 is proportional to the contrast, which is proportional to the magnitude of the derivative of the change. Therefore the resulting magnitude estimate is biased towards the direction of change once a certain level of change is detected.

The Screen Magnitude Estimator module SCM **54** in **FIG. 1** takes as input the Hi and Lo outputs of the two dual interpolation units. It then adds together the contributions from each of the channels as following:

$$SCM = \min(255,\ SCM_H + SCM_L)$$

Where

$$SCM_H = \max(0, (Hi - MagHiFrqThr) * MagHiFrqFac)$$

$$SCM_L = \max(0, (Lo - MagLoFrqThr) * MagLoFrqFac)$$

FIG. 11 is a diagram illustrating the above equations and the clipping effect of the additional logic which limits the value of HTW to the allowed range. The region denoted as "LA" **116** represents the line-art region. As illustrated in **FIG. 11**, one particular color screen pattern can change from the location indicated as LFHT to MFHT **124** to HFHT **126** as its frequency is changed from high to medium to low. Since the curve illustrated by the loci on the 2D plot is convex, it is not possible to distinguish the screen frequency by observing either LO or HI alone.

While certain exemplary embodiments have been described in detail and shown in the accompanying drawings, those of ordinary skill in the art will recognize that the invention is not limited to the embodiments described and that various modifications may be made to the illustrated and other embodiments of the invention described above, without departing from the broad inventive scope thereof. It will be understood, therefore, that the invention is not limited to the particular embodiments or arrangements disclosed, but is rather intended to cover any changes, adaptations or modifications which are within the scope and spirit of the invention as defined by the appended claims.